

## **REMARKS**

### **Summary of Amendments**

Upon entry of the present amendment claims 27-29, 34, 35, 37-42, and 44-59 will remain pending, with claims 27, 44, 53, 54 and 57-59 being independent claims. Claim 58 has been amended to correct an obvious error pointed out in Section 3. III. of the instant Office Action. All other claims are in their previously presented form, wherefore no new issues are raised and no new matter has been introduced. Accordingly, entry of the present amendment is respectfully requested.

### **Summary of Office Action**

Claims 44-52 are withdrawn from consideration as being drawn to a non-elected invention.

Claims 27-29, 34, 35, 37-42, and 53-59 are rejected under 35 U.S.C. § 112, second paragraph, as allegedly being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

Claims 27-29, 34, 35 and 37-42 remain rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over EPA 0842 967 by Jonschker et al. (hereafter "JONSCHKER").

Applicants note with appreciation that claims 53-59 are indicated to be allowable if rewritten to overcome the rejection(s) under 35 U.S.C. § 112, second paragraph and to include all of the limitations of the base claims and any intervening claims.

Clarification is requested regarding the filing date of the priority document of the present application as given in the translator's verification statement of the English language translation of the priority document submitted in response to the previous Office Action.

**Response to Office Action**

Withdrawal of the rejections of record is respectfully requested, in view of the foregoing amendments and the following remarks.

***Response to Rejection of Claims under 35 U.S.C. § 112, Second Paragraph***

Claims 27-29, 34, 35, 37-42, and 53-59 are rejected under 35 U.S.C. § 112, second paragraph, as allegedly being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

Regarding claims 55 and 56, it allegedly is unclear whether the particles recited therein are to satisfy the weight ratio requirement recited in claim 54 and whether individual particles are to further comprise the oxides recited in claims 55 and 56 or whether mixed oxides are not necessarily required.

In this regard, Applicants respectfully submit that the "particles" of claims 55 and 56 apparently are species of the generic "particles" that are recited in claim 54 (as indicated, for example, by the phrase "wherein the particles further comprise") and as such, are used in the weight ration recited in claim 54. No clarification is deemed necessary.

The Examiner's further inquiry regarding claims 55 and 56 is unclear to Applicants and clarification is respectfully requested. Claims 55 and 56 do not impose any restrictions as to the composition of individual particles and neither is any such restriction intended. Further, the use of one or more transition metal oxides is discussed at page 6, lines 25-35, and page 7, lines 20-39, of the present application.

Regarding claim 58, the Examiner correctly has pointed out an omission in this claim, i.e., "and" between "Zn" and "have". Amended claim 58 submitted herewith renders this rejection moot.

Regarding claims 27, 53, 54 and 57-59, the rejection alleges that it is unclear what is meant by the phrase "glass-forming elements" and that it is unclear what the boundaries of this phrase are. In particular, the Examiner inquires whether these elements in any compound suffice, whether oxygen in any compound suffices, whether the compound of glass-forming elements itself must be useful in forming a glass, and whether the compound must achieve a glass in the claimed process step of forming a coating.

Before specifically addressing the above rejection, Applicants point out that the MPEP provides guidance as to how to approach the requirement of definiteness of 35 U.S.C. § 112, second paragraph, during examination of claims. In particular, MPEP 2173.02 sets forth, in relevant parts:

The Examiner's focus during examination of the claims for compliance with the requirement for definiteness of 35 U.S.C. 112, second paragraph, is whether the claim meets the threshold

requirements of clarity and precision, not whether more suitable language or modes of expression are available. **When the examiner is satisfied that patentable subject matter is disclosed, and it is apparent to the examiner that the claims are directed to such patentable subject matter, he or she should allow claims which define the patentable subject matter with a reasonable degree of particularity and distinctness. Some latitude in the manner of expression and the aptness of terms should be permitted even though the claim language is not as precise as the examiner might desire.** Examiners are encouraged to suggest claim language to applicants to improve the clarity or precision of the language used, but should not reject claims or insist on their own preferences if other modes of expression selected by applicants satisfy the statutory requirement.

The essential inquiry pertaining to this requirement is whether the claims set out and circumscribe a particular subject matter with a reasonable degree of clarity and particularity. **Definiteness of claim language must be analyzed, not in a vacuum, but in light of:**

- (A) The content of the particular application disclosure;
- (B) The teachings of the prior art; and
- (C) **The claim interpretation that would be given by one possessing the ordinary level of skill in the pertinent art at the time the invention was made.**

Underlining in original. Bold face supplied.

Applicants note that the Examiner appears to be satisfied that at least claims 53-59 define patentable subject matter (see, e.g., page 3, last paragraph, of the present Office Action). The MPEP specifically instructs the examiner to allow corresponding claims "which define the patentable subject matter with a reasonable degree of particularity and distinctness" and to permit "some latitude in the manner of expression and the aptness of terms ... even though the claim language is not as precise as the examiner might desire."

Further, the MPEP points out that definiteness of claim language must be analyzed not in a vacuum, but in light of, *inter alia*, "the claim interpretation that would be given by one possessing the ordinary level of skill in the pertinent art at the time the invention was made".

In the present case, the questions as to the exact nature of the "compounds of glass-forming elements" raised by the Examiner would not appear to be of any relevance for the patentability of the claimed subject matter. In particular, the Examiner has not cited any reference which would render any of the present claims unpatentable if a specific example of the optional compounds of glass-forming elements (B) were to be used in combination with one or more of the silanes (A) for the preparation of the polycondensate recited in the present independent claims.

Further, one possessing the ordinary level of skill in the pertinent art at the time the invention was made would understand which compounds of glass-forming elements are suitable for making a polycondensate in combination with the compounds (silanes) (A) that are recited in the present independent claims. This person would also understand - particularly in light of the comments provided at page 4, lines 18-25 of the present application - which elements can be considered to be "glass-forming". In this regard, Applicants further note that a list of elements which may be used for making glass is also provided by the U.S.

Patent Classification in the definition of Class 65 (see pages 65-1, 65-6 and 65-85 of the "Classification Definitions" enclosed herewith)<sup>1</sup>.

Turning to the specific questions asked by the Examiner, according to the present independent claims, the coating material may, for example, comprise a polycondensate of (A) one or more specified silanes and (B) one or more compounds of glass-forming elements. This implies that the one or more compounds of glass-forming elements are capable of undergoing a condensation reaction with the silanes (A).

Further, the present claims do not require that the one or more compounds of glass-forming elements are themselves useful for forming a glass. It is sufficient for them to be compounds of elements which may be constituents of glass (and to be capable of forming a polycondensate with the silanes (A)). The technical term "glass-forming element" refers to elements which are capable of forming a glass. The formation of a glass is, however, also dependent on other factors such as the composition of the material. In this regard, it is noted that the present claims do not require the coating recited therein to be a glass coating.

The U.S. Patent Classification, page 65-1, refers to "an oxide which approaches glass forming properties". This indicates that oxygen is not usually considered to be a glass-forming element. Applicants note that glass is usually

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<sup>1</sup> In accordance with M.P.E.P. § 609C(3), the document cited above in support of Applicants' remarks is being submitted as evidence directed to an issue raised in the mentioned Office Action, and no additional fee or Certification pursuant to 37 C.F.R. §§ 1.97 and 1.98, or citation on a FORM PTO-1449 is believed to be necessary.

regarded as an amorphous oxide of one or more glass-forming elements which are different from oxygen.

Applicants submit that for at least the reasons given above, the rejections of the present claims under 35 U.S.C. 112, second paragraph, are without merit and withdrawal thereof is warranted, which action is respectfully requested.

***Response to the Rejection of the Claims under 35 U.S.C. § 103(a) over  
JONSCHKER***

Claims 27-29, 34, 35 and 37-42 stand rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over JONSCHKER for the reasons of record in the Office Action mailed on June 4, 2004. Accordingly, the rejection contends that JONSCHKER teaches a polycondensate of silane and metal oxide particles on a substrate, and that titanium oxide particles are described as effective metal oxide particles, which titanium oxide particles allegedly are inherently catalytic. Since in the response to the rejection in the Office Action of June 4, 2004, Applicants have challenged the contention that titanium dioxide is inherently catalytically active in a deodorization or oxidation process, in the present Office Action the Examiner relies on a document, i.e., U.S. Published Application 2004/0229540 by Akiba et al. (hereafter "AKIBA") which allegedly "teaches that titanium dioxide inherently behaves as a photo-catalyst in oxidation processes".

Applicants respectfully traverse this rejection. Even the passage of AKIBA which is relied on by the Examiner, i.e., paragraph 33 thereof, does not appear to

unambiguously teach that each and every form of titanium dioxide is photocatalytically active. Rather, AKIBA refers to "optical semiconductors" and mentions titanium dioxide as a specific and preferred example thereof. AKIBA mentions that the crystal structure of the optical semiconductor constituting the photocatalyst is not particularly limited to a specific one and that "TiO<sub>2</sub> may be in any form such as an anatase form, a brookite form, a rutile form, and an amorphous form". However, the use of the phrase "optical semiconductor" appears to suggest that not each and every form of TiO<sub>2</sub> qualifies as such an "optical semiconductor".

Also, in the examples thereof, AKIBA only shows the use of titanium dioxide which is made by specific processes. Further, in Comparative Example 3 of AKIBA it is pointed out that the anatase titanium dioxide employed therein has photocatalytic activity. If AKIBA taught that each and every form of TiO<sub>2</sub> is inherently catalytically active, it would not have to be pointed out that the anatase titanium dioxide has this property.<sup>2</sup>

Additionally, enclosed herewith are pages 1-9 of an article downloaded from the Internet ([http://www.ott.doe.gov/coolcar/pdfs/cancer\\_cells.pdf](http://www.ott.doe.gov/coolcar/pdfs/cancer_cells.pdf)), i.e., D.M. Blake et al., "APPLICATION OF THE PHOTOCATALYTIC CHEMISTRY OF TITANIUM DIOXIDE TO DISINFECTION AND THE KILLING OF CANCER CELLS" in "Separation and Purification Methods",

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<sup>2</sup> Merely as a matter of precaution it is pointed out that AKIBA was published only on November 18, 2004 and thus, is not available as prior art against the present claims.



Volume 28(1) 1999, pp.1-50<sup>3</sup>. At page 6 of this document, under the heading "Mode of action of TiO<sub>2</sub>", it is clearly stated that "two crystalline forms of TiO<sub>2</sub> have photocatalytic activity, anatase and rutile". If one were to assume that TiO<sub>2</sub> in general (i.e., regardless of its crystal structure) has photocatalytic activity this statement would not make any sense. Accordingly, contrary to the contention underlying the present rejection, this scientific article implies that TiO<sub>2</sub> in general is not inherently photocatalytically active, i.e., only specific (crystalline) forms thereof show this property.

At least for the reasons set forth above, Applicants still disagree with the Examiner's analysis of JONSCHKER and the conclusions drawn therefrom. As already pointed out in response to the previous Office Actions, JONSCHKER does not address any catalytic properties of the composite material disclosed therein, let alone catalytic properties of the colloidal inorganic particles used for the production of this composite.

Moreover, the materials to be contacted with the composite according to JONSCHKER, i.e., substrates based on glass fibers, mineral fibers and wood materials (see, e.g., claim 1 of JONSCHKER) would not appear to benefit in any respect from any oxidative or deodorizing catalytic activity of the composite, as recited in the present claims. In this regard it is noted that in Examples 1 and 2 of

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<sup>3</sup> In accordance with M.P.E.P. § 609C(3), the document cited above in support of Applicants' remarks is being submitted as evidence directed to an issue raised in the mentioned Office Action, and no additional fee or Certification pursuant to 37 C.F.R. §§ 1.97 and 1.98, or citation on a FORM PTO-1449 is believed to be necessary.

JONSCHKER, the burning behavior of corresponding substrates is discussed. Example 3 describes the production of a mechanically stable shaped body with a content of 1 % by weight of rock wool granules. Further, titanium dioxide is not mentioned in any of the examples of JONSCHKER.

To sum up, for at least the reasons set forth above, JONSCHKER does not render obvious the subject matter of any of the claims submitted herewith. Accordingly, withdrawal of the rejection of the claims under 35 U.S.C. § 103(a) as obvious over this document is warranted and again respectfully requested.

***Response to Inquiry Regarding Filing Date of Priority Document***

At page 5 of the present Office Action the Examiner requests clarification regarding the filing date of the priority document of the present application as given in the translator's verification statement of the English language translation of the priority document submitted in response to the previous Office Action. As correctly assumed by the Examiner, the listed filing date was a mistake and should correctly have read 6 April 1999 (instead of 6 April 2000). In view thereof, Applicants note with appreciation that the rejection of the claims in the previous Office Action over NISHIMORI under 35 U.S.C. § 102(a) is withdrawn.

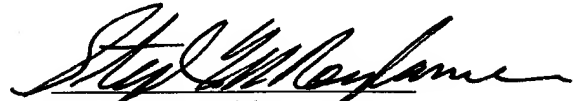
**CONCLUSION**

In view of the foregoing, it is believed that all of the claims in this application are in condition for allowance, which action is respectfully requested.

P24820.A05

If any issues yet remain which can be resolved by a telephone conference, the Examiner is respectfully invited to contact the undersigned at the telephone number listed below.

Respectfully submitted,  
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**Separation and Purification Methods**  
**Volume 28(1) 1999, pp. 1-50**

**APPLICATION OF THE PHOTOCATALYTIC CHEMISTRY OF  
TITANIUM DIOXIDE TO DISINFECTION AND THE KILLING  
OF CANCER CELLS**

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## **Abstract**

This article will review the work that has been published on disinfection and the killing of cancer cells using photocatalytic chemistry with titanium dioxide (TiO<sub>2</sub>). This is an application of photocatalytic chemistry that has been under active investigation since 1985. Because the nature of the research is such that it brings together disparate disciplines, this review provides background on photocatalytic chemistry, fundamental characteristics of target organisms, potential applications, and the toxicology of titanium dioxide. Literature identified in searches done through September 1998 is included.

## **Introduction**

This article will review the work that has been published worldwide on disinfection and the killing of cancer cells using photocatalytic chemistry with titanium dioxide (TiO<sub>2</sub>). Health effects of titanium dioxide are also covered since applications of photocatalytic technology will bring a range of organisms into contact with crystalline and particulate forms of the photocatalyst. This is an application of photocatalysis that has been receiving increasing attention since the first report of microbiocidal effects by Matsunaga, Tomada, Nakajima, and Wake in 1985.<sup>1</sup> The research community that has been most active in the study of photocatalytic chemistry is composed mainly of chemists and chemical engineers who are often unfamiliar with the terms used by the microbiologist. Microbiologists for their part may be less familiar with the photochemistry and reactor issues associated with photocatalytic systems. For this reason this review will provide a brief introduction to the structure of target organisms and to current practices for disinfection as

required to discuss the interaction of microorganisms with activated photocatalyst surfaces and the chemical species produced when titanium dioxide surfaces are irradiated. Patent literature that includes claims related to this topic is also included. Titanium dioxide has been used extensively as a white pigment and as a cosmetic ingredient. Literature that studies the potential health effects of TiO<sub>2</sub> exposure is also included in this review.

Photocatalytic chemistry of titanium dioxide has been extensively studied over the last 25 years for removal of organic and inorganic compounds from contaminated water and air and for the partial oxidation of organic compounds. The most active photocatalysts are formulations based on the anatase crystal phase, and most work has been done using the P25 form of TiO<sub>2</sub> produced by Degussa Chemical Company (Germany). This material is a mixture of phases with an approximate composition of 75% anatase and 25% rutile and has a BET surface area of about 50 m<sup>2</sup>/g. The literature for the photocatalytic oxidation or reduction of organic and inorganic compounds has been the subject of comprehensive bibliographies<sup>2,3,4</sup> and numerous reviews.<sup>5,6,7,8,9</sup>

Engineering requirements for practical photocatalytic systems have been discussed.<sup>10</sup>

A recent review includes some coverage of the application of photocatalytic chemistry to disinfection.<sup>11</sup> Work by Japanese groups has been included in short reviews.<sup>12,13,14</sup>

## **Background**

There are many circumstances where it is necessary or desirable to remove or kill microorganisms found in water, air, on surfaces, or in a biological host. Disinfection of water is required for direct human consumption as well as in the production of products to be consumed by humans or animals. Disinfection of air is required in medical facilities, in production processes where biological contamination must be prevented, and in facilities that raise or care for experimental animals and plants that may be sensitive to infectious agents. Disinfection can require the removal or deactivation of pathogenic bacteria, viruses, protozoa, or fungi. The status of methods to disinfect drinking water has been reviewed.<sup>15,16,17</sup> This is a particular challenge in rural areas of developing countries. The most widely used methods in developed countries are chlorination and ozonation, but germicidal lamps (low pressure mercury vapor lamps emitting at

254 nm) are being evaluated and used on a large scale. Disinfection of air can be accomplished by the use of germicidal lamps<sup>18</sup> or size exclusion filters (high efficiency particle air, HEPA, filters).<sup>19,20,21</sup> Biocides are widely used for control of biofilm growth in cooling towers and chilled water systems. Surfaces can be disinfected by ozone exposure, irradiation with UV light, washing with disinfectants, or application of heat.<sup>22</sup> Some of the methods relevant to this review are summarized in Table I and compared with the modes of action proposed for TiO<sub>2</sub> systems.

TABLE I. Modes of microbe removal or killing action for various disinfection methods.

Method	OH	O <sub>2</sub> <sup>-</sup> , H <sub>2</sub> O <sub>2</sub>	Cl	hν	Adsorption	Trapping
UV (254 nm)				x		
Chlorine			x			
TiO <sub>2</sub> (300-380 nm)	x	x		(a)	x	(b)
TiO <sub>2</sub> (254 nm)	x	x		x	x	(b)
HEPA filter						x

(a) Near ultraviolet light may have some killing effect on sensitive organisms.

(b) In some catalyst configurations the titanium dioxide layer may act as a particle filter.

Photocatalytic methods are unique in having several modes of action that can be brought to bear on disinfection. The target of disinfection processes are pathogenic organisms including viruses, bacteria, fungi, protozoa, and algae. Each presents a challenge in terms of the structure and defense mechanisms that must be overcome. The current disinfection technologies rely on chemical or photochemical induced damage or physical removal by filtration. Mechanisms for the killing of cells by conventional methods have been covered in earlier reviews.<sup>15,16,23,24,25</sup> Irradiation from germicidal lamps, 254 nm, results in cross-linking of thymine groups in DNA. Free radicals such as chlorine atom or hydroxyl radical, OH<sup>•</sup>, can result in DNA strand breakage

or initiate autoxidation of lipids or other cell components. Ozone or singlet oxygen can attack molecular structures found in cell components with some selectivity.

Organisms have evolved defense and repair mechanisms to overcome photochemical and oxidative damage that allow them to live in an aerobic environment and to deal with the low levels of UV radiation found in sunlight. All life forms are sensitive to damage to DNA macromolecules, therefore, nature has equipped cells with several defense and repair mechanisms against such damage. In particular ultraviolet light in the germicidal range around 254 nm causes the adjacent thymine bases on a DNA strand to form a thymine dimer, thus blocking protein synthesis and disabling the proper replication of the DNA helix during cell division cycle. Cells then respond by either undergoing a photochemical repair using a photolyase enzyme, or by dark excision repair using endonuclease, exonuclease, DNA polymerase, and ligase enzymes.<sup>24,26,27</sup>

It is well documented that an increased pressure of oxygen is toxic to all forms of life, and the production of oxygen radicals is the root cause of oxygen toxicity. During respiration the stepwise reduction of oxygen leading to H<sub>2</sub>O generates the reactive intermediates superoxide radical (O<sub>2</sub><sup>-</sup>) and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), both of which are reactive toward biological macromolecules and can be precursors for hydroxyl radical.<sup>28</sup> Therefore, all organisms prevailing in the aerobic atmosphere have evolved a protective mechanism to scavenge both O<sub>2</sub><sup>-</sup> and H<sub>2</sub>O<sub>2</sub> to a very low steady-state concentration.

Indeed, all aerobic life forms are reported to have a superoxide dismutase (SOD) enzyme to dismutate O<sub>2</sub><sup>-</sup> to H<sub>2</sub>O<sub>2</sub> and O<sub>2</sub>, and a catalase enzyme to convert H<sub>2</sub>O<sub>2</sub> to H<sub>2</sub>O and additional O<sub>2</sub> as innocuous end products.<sup>29,30</sup> Several procaryotes including *E. coli*, have evolved to produce different forms of SOD strategically distributed within a cell to shield the cells from any oxidative damage resulting from their normal metabolism. In *E. coli*, an Fe-SOD is distributed along the periphery of the cytoplasm close to the inner membrane to dissipate any radicals produced from aerobic respiratory pathways. A second cytoplasmic Mn-SOD is more abundant in the central region of the cell where the nucleoid is in order to protect DNA from damage caused by oxidants. A third Cu,Zn-SOD, found exclusively in the periplasm, is proposed to



guard the cells from any exogenous source of  $O_2^-$ , whether produced from the immediate hostile environment or by other phagocytic cells.<sup>25</sup>

In some cases it is not sufficient to kill or remove the microorganism responsible for a pathogenic or allergic response. Some bacteria produce endotoxins and exotoxins. Some Gram-positive bacteria and, less commonly, Gram-negative bacteria release exotoxins into the medium of the growing culture. These are most often heat sensitive proteins. Endotoxins are most frequently produced within Gram-negative bacteria and are not released unless the outer membrane becomes damaged. Endotoxins are usually lipopolysaccharides. Contact with these compounds can give rise to medical problems, and allergic responses can be caused by cell structures that persist even after the cell is no longer viable.<sup>31</sup>

### **Mode of action of $TiO_2$**

Two crystalline forms of  $TiO_2$  have photocatalytic activity, anatase and rutile. Anatase has a band gap of 3.2 eV and for rutile it is 3.0 eV. Anatase has been found to be the most active form. The action spectrum for anatase shows a sharp decrease in activity above about 385 nm. The photocatalytic process includes chemical steps that produce reactive species that in principal can cause fatal damage to microorganisms.<sup>5,6,7, 8,11</sup> The steps are summarized in Table II and include formation of the following species: hydroxyl radical, hydrogen peroxide, superoxide, conduction band electron, and valence band hole.<sup>32</sup> Formation of singlet oxygen on irradiated  $TiO_2$  has also been reported<sup>33</sup> but is not usually considered to be present under the usual conditions of disinfection reactions. The reactive oxygen species (ROS) may disrupt or damage various cell or viral functions or structures. The preponderance of evidence on photocatalytic chemistry in aqueous solution suggests that the hydroxyl radical formed by hole transfer does not diffuse from the surface of the  $TiO_2$  into bulk aqueous phase.<sup>34</sup>

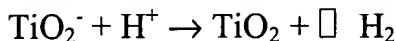
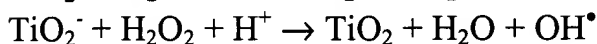
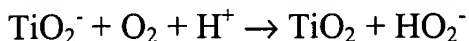
For a cell or virus in contact with the titanium dioxide surface there may also be direct electron or hole transfer to the organism or one of its components. If titanium dioxide particles are of

TABLE II. Mechanism of a photocatalytic process on irradiated titanium dioxide.

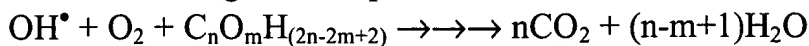
### Electron-Hole Pair Formation

$\text{TiO}_2 + h\nu \rightarrow \text{TiO}_2^- + \text{OH}^\bullet$  (or  $\text{TiO}_2^+$ ) (conduction band electron and valence band hole)

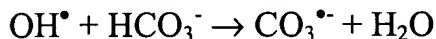
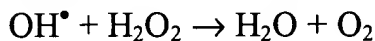
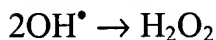
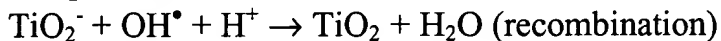
### Electron removal from the conduction band



### Oxidation of organic compounds



### Nonproductive Radical Reactions



small size, they may penetrate into the cell and these processes could occur in the interior. Since light is an essential component of the photocatalytic system, there can also be direct photochemistry as there would be from any UV source. There is also the possibility for enhanced or unique photochemistry resulting from the irradiation of the microbe while it is adsorbed on an oxide surface, as has been observed for molecules.<sup>35</sup> The relative sizes of molecular or biological targets of photocatalytic chemistry and the most commonly used form of  $\text{TiO}_2$ , Degussa P25, may have some significance. These are given in Table III. Orientation and distance effects are likely to be more pronounced in the case of microbes which are comparable in size to aggregates of the titanium dioxide particles.

Hydroxyl radicals are highly reactive and therefore short-lived. Superoxide ions are more long-lived; however, due to the negative charge they cannot penetrate the cell membrane. Upon their

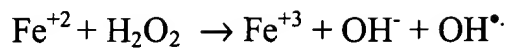
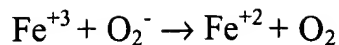
TABLE III. Relative sizes of TiO<sub>2</sub> particles and target or other representative species that may be present in media being treated.

<u>Species</u>	<u>Size, microns</u>
Benzene Molecule	0.00043
TiO <sub>2</sub> Crystalite (Degussa P25)	0.03
TiO <sub>2</sub> Agglomerate (in water)	1-3
Virus	0.01-0.3
E. coli (rod shape)	1 X 3
Yeast Cell	1-5 X 5-30
Protozoa	1-2000
Atmospheric Dust	0.001-13
Tobacco Smoke	0.01-1

production on the TiO<sub>2</sub> surface, both hydroxyl radicals and superoxide would have to interact immediately with the outer surface of an organism unless the TiO<sub>2</sub> particle has penetrated into the cell. Compared to hydroxyl radicals and superoxide ions, hydrogen peroxide is less detrimental. However, hydrogen peroxide can enter the cell and be activated by ferrous ion via the Fenton reaction.



The ability of bacteria, such as *E. coli*, to sequester iron is well documented.<sup>36,37</sup> Iron levels on the cell surface, in the periplasmic space or inside the cell, either as iron clusters or in iron storage proteins (such as ferritin) are significant and can serve as a source of ferrous ion. Therefore, while the TiO<sub>2</sub> is being illuminated to produce H<sub>2</sub>O<sub>2</sub>, the Fenton reaction may take place *in vivo* and produce the more damaging hydroxyl radicals.<sup>38,39</sup> When the light is turned off, any residual hydrogen peroxide would continue to interact with the iron species and generate additional hydroxyl radicals through the Fenton reaction. When both H<sub>2</sub>O<sub>2</sub> and superoxide ion are present, the iron-catalyzed Haber-Weiss reaction can provide a second pathway to form additional hydroxyl radicals.<sup>40</sup>



Since the initial actions of these reactive oxygen species (ROS) target the outer surface of a cell, the rigidity and chemical arrangements of their surface structure will determine how effectively the TiO<sub>2</sub> photocatalytic disinfection process functions.

### **Photocatalytic Reactor Configurations**

Photocatalytic reactors are designed to operate in either a liquid-solid system (*e.g.*, water disinfection) or a gas-solid system (*e.g.*, air disinfection). The two systems have implications with respect to reactor design. Another important distinction is whether the catalyst is fixed, *i.e.* immobile within the system, or moveable. Therefore, photocatalytic reactors fall into four broad categories:<sup>5,10,11</sup>

1) Liquid-solid, moveable bed reactors. These systems typically involve slurries of TiO<sub>2</sub> suspended in the liquid to be treated. The concentration of TiO<sub>2</sub> typically ranges between 0.05% and 1% by weight. Light penetration limitations prevent the use of higher concentrations. The catalyst flows into and out of the reactor with the liquid being treated. Typically either natural or artificial irradiation sources are external to the system, and the photons are transmitted through UV-transparent ports. A subsequent separation step is necessary to remove the TiO<sub>2</sub> from the treated water.

2) Liquid-solid, fixed bed reactors. Due to lower reaction rates, these systems are uncommon. The relatively low extent of contact between the catalyst and the molecules to be oxidized leads to mass transport limitations in fixed bed aqueous systems.

3) Gas-solid moveable bed reactors. Fluidized bed systems have been studied for destruction of chemicals in air. The catalyst particles are not entrained in the air stream. Rather, in a properly

**CLASS 65, GLASS MANUFACTURING****SECTION I - CLASS DEFINITION**

This class provides for (1) processes and/or apparatus for making stock or articles of those ceramic masses, which generally include a "glass former" or an oxide which approaches glass forming properties, in their composition and which are formed by fusion of raw materials (generally mixtures, most of which are of an earthy nature - as distinguished from metallic, organic, etc., - silicon, silica, and slag are included) at ordinary high furnace temperatures, by working (molding, shaping, etc.) of the mass after being melted or changed to a plastic or softened state by heating; and (2) processes and/or apparatus for treating stock or articles made by (1) above unless otherwise provided for as shown in Lines With Other Classes and Within This Class and References to Other Classes, below.

The use of hazardous or toxic waste to make a glass material a useful product is provided for herein, however, vitrification of hazardous waste for purposes of containment is excluded, see References to Other Classes below.

Included within the scope of the class definition are:

- (1) Glass fiber or filament and mineral wool making.
- (2) Manufacturing processes and/or apparatus including a step of, or means for adhesively bonding glass directly to another part by welding with or without use of an intermediate ceramic or vitreous material.
- (3) Manufacturing processes and/or apparatus including a step of, or means for forming a glass article from molten or softened glass.
- (4) Processes and/or apparatus including a step of, or means for treating glass while in a molten or solid state.
- (5) Processes and/or apparatus including a step of, or means for treating a glass preform to change a physical or chemical property thereof.
- (6) Processes and/or apparatus for repairing or cleaning glass working or treating apparatus.

**SECTION II - LINES WITH OTHER CLASSES AND WITHIN THIS CLASS**

Search notes relating to (a) processes and apparatus and (b) products will be identified appropriately.

**LINES WITH CLASS 23, CLASS 117, AND CLASS 438**

Although silicon and silicon dioxide are arbitrarily considered to be glass materials for Class 65, a process of growing these polycrystalline materials is proper for Class 23, even though a rod is used as a bait, unless the shape formed is not a result of crystallization or deposition on the rod. If crystallization is combined with specific glassworking and/or treating of silicon or silicon dioxide, the process is proper for Class 65, but see Class 438 for semiconductor device manufacture. Processes of growing single-crystal of all types of materials, including silicon or silicon dioxide, are proper for Class 117. The proper placement of the original of a patent claiming a Class 23 and/or Class 117 species of crystallization and a Class 65 species, or having multiple disclosure with only generic claims, is Class 117 first, then Class 23, then Class 65.

**LINES WITH CLASS 422, CLASS 23, AND CLASS 148**

See Class 422, Chemical Apparatus and Process Disinfecting, Deodorizing, Preserving, or Sterilizing, subclasses 245.1+ for apparatus directed to crystallizing a material within the class definition of Class 23. Although silicon and silicon dioxide are arbitrarily considered to be glass for Class 65, a process of, or apparatus for, growing crystals of these materials is placed in Class 23 (for a process exception, see (5) Note in Class 148, subclasses 1.5+) even though a rod is used as a bait unless the shape formed is not a result of crystallization or deposition on the rod. A combination of crystallization and specific glassworking and/or treating silicon or silicon dioxide is placed in Class 65. A patent claiming a Class 23 species of crystallization and a Class 65 species or having a multiple disclosure with generic claims only is classified in Class 23.

**LINES WITH CLASS 438 AND CLASS 437**

Class 438, Semiconductor Device Manufacturing: Process, for the combination of Class 437 unit coating operation or Class 437 unit etching operation with glass melting, shaping or forming, joining, or heat treating. Moreover, Class 438 also takes the heat treating, per se, of Class 438 semiconductor material if for purposes of modifying the electrical properties thereof. Additionally, various classes take mounting or packaging operations

**DRAW RING**

A refractory device placed in a supply of molten glass to define an area for drawing.

**DRAW SHIELD**

Baffle means isolating stock being drawn from the hot atmosphere existing above a supply of molten glass.

**EMBOSSING**

Altering a surface configuration only of glass by raising a boss or protuberance thereon or causing surface portions to be depressed below the plane of the glass surface.

**FIBER**

See Subclass References to the Current Class, above, for a subclass reference to the term "fiber."

**FILAMENT**

See Subclass References to the Current Class, above, for a subclass reference to the term "filament."

**FINING**

See Subclass References to the Current Class, above, for a subclass reference to the term "fining."

**FIRE-POLISHING**

Heating of the outer surface of hard glass to a temperature where that surface only melts and surface tension causes smoothing thereof, the heating usually being by fire or flame contact of the glass surface.

**FLASHING**

Applying a thin layer of opaque or colored glass to the surface of clear glass, or vice versa.

**FLOATERS**

Refractory blocks floating on molten glass in a tank furnace to prevent gall or scum from entering the working end.

**FUSION BONDING**

Welding by bringing glass, while molten or softened by

heating, into intimate contact with another part with subsequent cooling to solid phase whereby uniting is effected.

**GATHERER**

Means used to remove discrete charges of molten glass from a supply.

**GLASS**

An inorganic product (a) the constituents of which generally include a "glass former" (e.g.,  $\text{As}_2\text{O}_3$ ,  $\text{B}_2\text{O}_3$ ,  $\text{GeO}_2$ ,  $\text{P}_2\text{O}_5$ ,  $\text{SiO}_2$ ,  $\text{V}_2\text{O}_5$ ) which has an essential characteristic of creating or maintaining, singly, or in a mixture, that type of structural disorder characteristic of a glassy condition, other oxides which approach glass forming properties (e.g.,  $\text{Al}_2\text{O}_3$ ,  $\text{BeO}$ ,  $\text{PbO}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{ZnO}$  and  $\text{ZrO}_2$ ) as well as oxides that are practically devoid of glass forming tendencies (e.g.,  $\text{BaO}$ ,  $\text{CaO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Li}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$  and  $\text{SrO}$ ), however, pure and modified silica, silicon and slag are also included; (b) formed by fusion and cooled to a rigid condition generally without crystallization; (c) having no definite melting point (whereby the mass has the characteristic of passing through a plastic state before reaching a liquid state when heated); (d) incapable in the solid state of permanent deformation; and (e) which fractures when subject to deformation tension.

**GLASS TREATING**

Effecting a change in a physical or chemical property of glass, generally involving specific heating followed by controlled cooling.

**GLASS WORKING**

Molding, shaping, severing or uniting of glass while in a plastic state.

**GOB**

A discrete portion of molten glass (a) delivered by a feeder or (b) gathered on a punty or blow pipe.

**HOMOGENIZE**

See Subclass References to the Current Class, above, for a subclass reference to the term "homogenize."

**MARVERING**

**439 Producing hollow fibers or tubular preforms:**

This subclass is indented under subclass 376. Processes wherein the glass fiber or tubular preform produced has a hollow core or an empty cavity.

**440 Sol-gel route or ion exchange utilized:**

This subclass is indented under subclass 376. Processes wherein (a) a sol-gel route or (b) an exchanging of selected ions is used during any stage of manufacturing or treating the glass fiber, filament or preform.

- (1) Note. The sol-gel route process generally includes compositions which have been prepared by a method other than melting having at least one step in which the glass forming ingredients are in a gel or sol state.

**441 Electromagnetic, magnetic, wave, or particulate energy utilized:**

This subclass is indented under subclass 376. Processes involving the use of electrical, magnetic, particulate, or electromagnetic wave energy during any stage of forming or treating the glass fiber, filament, or preform.

- (1) Note. The wave energy applied may be light, sonic, supersonic, ultrasonic, gamma rays, infrared rays, X-rays etc. Particulate energy includes charged particles and atomic emissions, such as alpha rays, beta rays, and neutrons.
- (2) Note. Patent documents claiming the use of electrostatic charge, field, or force to form or treat a glass fiber, filament, or preform are properly classified herein.
- (3) Note. Patent documents claiming the use of electric arc heating to form a glass fiber are properly classified herein.

SEE OR SEARCH THIS CLASS, SUBCLASS:

- 425, for processes wherein the electrical, magnetic, wave, or particulate energy is used to form an optical fiber, waveguide, or preform.

- 509, for fiber making apparatus utilizing electric or electromagnetic wave energy.

SEE OR SEARCH CLASS:

- 250, Radiant Energy, appropriate subclasses, especially subclasses 492.1+ for irradiation treatment, per se, of a glass fiber, filament or preform without any glassworking step (e.g., melting, shaping, etc.).

**442 Composite fiber matrix (e.g., carbon or metal fiber with glass matrix or vice versa, etc.):**

This subclass is indented under subclass 376. Processes including a step of surrounding or encasing the fiber or filament by a different material (e.g., binder, etc.).

**443 With coating (e.g., lubricant, sizing, etc.):**

This subclass is indented under subclass 376. Processes including a step of applying a coating material to the fibers, filaments, or preforms which clings thereto.

SEE OR SEARCH THIS CLASS, SUBCLASS:

- 43, and 60.1+, for processes of coating nonfilamentary glass combined with glassworking or treating, and see the SEARCH CLASS notes thereunder.

**444 Glass (i.e., nonoptical fiber, metal oxide):**

This subclass is indented under subclass 443. Processes wherein the coating material for the glass fibers, filaments, or fiber preforms is itself a glass composition.

SEE OR SEARCH THIS CLASS, SUBCLASS:

- 405, for multiple crucible methods of making glass coated optical fibers.

**445 Free metal or alloy containing:**

This subclass is indented under subclass 443. Processes wherein the coating material contains elemental metal or metal alloy.